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School Science

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THE CONSTRUCTION OF A MODEL OF NATURE.

AND

THE LIMITS OF PHYSICAL THEORIES.*

BY ARTHUR W. RÜCKER.

A natural philosopher, to use the old phrase, even if only possessed of a most superficial knowledge, would attempt to bring some order into the results of his observation of nature by grouping together statements with regard to phenomena which are obviously related. The aim of modern science goes far beyond this. It not only shows that many phenomena are related which at first sight have little or nothing in common, but, in so doing, also attempts to explain the relationship.

Without spending time on a discussion of the meaning of the word "explanation," it is sufficient to say that our efforts to establish relationships between phenomena often take the form of attempting to prove that, if a limited number of assumptions are granted as to the constitution of matter, or as to the existence of quasi material entities, such as caloric, electricity and the ether, a wide range of observed facts falls into order as a necessary consequence of the assumptions. The question at issue is whether the hypotheses which are at the base of the scientific theories now most generally accepted are to be regarded as accurate descriptions of the constitution of the universe around us, or merely as convenient fictions.

Convenient fictions, be it observed, for even if they are fic-

*From the address of the President of the British Association for the Advancement of Science, Glasgow meeting, 1901.

tions they are not useless. From the practical point of view it is a matter of secondary importance whether our theories and assumptions are correct, if only they guide us to results which are in accord with facts. The whole fabric of scientific theory may be regarded merely as a gigantic "aid to memory"; as a means for producing apparent order out of disorder by codifying the observed facts and laws in accordance with an artificial system, and thus arranging our knowledge under a comparatively small number of heads. The simplification introduced by a scheme which, however imperfect it may be, enables us to argue from a few first principles, makes theories of practical use. By means of them we can foresee the results of combinations of causes which would otherwise elude us. We can predict future events, and can even attempt to argue back from the present to the unknown past.

But it is possible that these advantages might be attained by means of axioms, assumptions and theories based on very false ideas. A person who thought that a river was really a streak of blue paint might learn as much about its direction from a map as one who knew it as it is. It is thus conceivable that we might be able, not indeed to construct, but to imagine, something more than a mere map or diagram, something which might even be called a working model of inanimate objects, which was nevertheless very unlike the realities of nature. Of course, the agreement between the action of the model and the behavior of the things it was designed to represent would probably be imperfect, unless the one were a facsimile of the other; but it is conceivable that the correlation of natural phenomena could be imitated, with a large measure of success, by means of an imaginary machine which shared with a map or diagram the characteristic that it was in many ways unlike the things it represented, but might be compared to a model in that the behavior of the things represented could be predicted from that of the corresponding parts of the machine.

We might even go a step further. If the laws of the working of the model could be expressed by abstractions, as, for example, by mathematical formulæ, then, when the formulæ were obtained,

the model might be discarded, as probably unlike that which it was made to imitate, as a mere aid in the construction of equations, to be thrown aside when the perfect structure of mathematical symbols was erected.

If this course were adopted we should have given up the attempt to know more of the nature of the objects which surround us than can be gained by direct observation, but might nevertheless have learned how these objects would behave under given circumstances.

We should have abandoned the hope of a physical explanation of the properties of inanimate nature, but should have secured a mathematical description of her operations.

There is no doubt that this is the easiest path to follow. Criticism is avoided if we admit from the first that we can not go below the surface; can not show anything about the constitution of material bodies; but must be content with formulating a description of their behavior by means of laws of nature expressed by equations.

But if this is to be the end of the study of nature, it is evident that the construction of the model is not an essential part of the process. The model is used merely as an aid to thinking; and if the relations of phenomena can be investigated without it, so much the better. The highest form of theory—it may be said—the widest kind of generalization, is that which has given up the attempt to form clear mental pictures of the constitution of matter, which expresses the facts and the laws by language and symbols which lead to results that are true, whatever be our view as to the real nature of the objects with which we deal. From this point of view the atomic theory becomes not so much false as unnecessary; it may be regarded as an attempt to give an unnatural precision to ideas which are and must be vague.

Thus, when Rumford found that the mere friction of metals produced heat in unlimited quantity, and argued that heat was therefore a mode of motion, he formed a clear mental picture of what he believed to be occurring. But his experiments may be quoted as proving only that energy can be supplied to a body in

indefinite quantity, and when supplied by doing work against friction it appears in the form of heat.

By using this phraseology we exchange a vivid conception of moving atoms for a colorless statement as to heat energy, the real nature of which we do not attempt to define; and methods which thus evade the problem of the nature of the things which the symbols in our equations represent have been prosecuted with striking success, at all events within the range of a limited class of phenomena. A great school of chemists, building upon the thermodynamics of Willard Gibbs and the intuition of Van't Hoff, have shown with wonderful skill that, if a sufficient number of the data of experiment are assumed, it is possible, by the aid of thermodynamics, to trace the form of the relations between many physical and chemical phenomena without the help of the atomic theory.

But this method deals only with matter as our coarse senses know it; it does not pretend to penetrate beneath the surface.

It is therefore with the greatest respect for its authors, and with a full recognition of the enormous power of the weapons employed, that I venture to assert that the exposition of such a system of tactics cannot be regarded as the last word of science in the struggle for the truth.

Whether we grapple with them, or whether we shirk them; however much or however little we can accomplish without answering them, the questions still force themselves upon us: Is matter what it seems to be? Is interplanetary space full or empty? Can we argue back from the direct impressions of our senses to things which we cannot directly perceive; from the phenomena displayed by matter to the constitution of matter itself?

It is these questions which we are discussing tonight, and we may therefore, as far as the present address is concerned, put aside, once for all, methods of scientific exposition in which an attempt to form a mental picture of the constitution of matter is practically abandoned, and devote ourselves to the inquiries whether the effort to form such a picture is legitimate, and whether we have any reason to believe that the sketch which science has already drawn is to some extent a copy, and not a mere diagram, of the truth.

THE LIMITS OF PHYSICAL THEORIES.

And this brings me to my last point. It is a mistake to treat physical theories in general, and the atomic theory in particular, as though they were parts of a scheme which has failed if it leaves anything unexplained, which must be carried on indefinitely on exactly the same principles, whether the ultimate results are, or are not, repugnant to common sense.

Physical theories begin at the surface with phenomena which directly affect our senses. When they are used in the attempt to penetrate deeper into the secrets of nature it is more than probable that they will meet with insuperable barriers, but this fact does not demonstrate that the fundamental assumptions are false, and the question as to whether any particular obstacle will be forever insuperable can rarely be answered with certainty.

Those who belittle the ideas which have of late governed the advance of scientific theory too often assume that there is no alternative between the opposing assertions that atoms and the ether are mere figments of the scientific imagination, or that, on the other hand, a mechanical theory of the atoms and of the ether, which is now confessedly imperfect, would, if it could be perfected, give us a full and adequate representation of the underlying realities.

For my own part I believe that there is a *via media.*

A man peering into a darkened room, and describing what he thinks he sees, may be right as to the general outline of the objects he discerns, wrong as to their nature and their precise forms. In his description fact and fancy may be blended, and it may be difficult to say where the one ends and the other begins; but even the fancies will not be worthless if they are based on a fragment of truth, which will prevent the explorer from walking into a looking-glass or stumbling over the furniture. He who saw "men as trees walking" had at least a perception of the fundamental fact that something was in motion around him.

And so, at the beginning of the twentieth century, we are neither forced to abandon the claim to have penetrated below the surface of nature, nor have we, with all our searching, torn the veil of mystery from the world around us.

The range of our speculations is limited both in space and time: in space, for we have no right to claim, as is sometimes done, a knowledge of the "infinite universe"; in time, for the cumulative effects of actions which might pass undetected in the short span of years of which we have knowledge, may, if continued long enough, modify our most profound generalizations. If some such theory as the vortex-atom theory were true, the faintest trace of viscosity in the primordial medium would ultimately destroy matter of every kind. It is thus a duty to state what we believe we know in the most cautious terms, but it is equally a duty not to yield to mere vague doubts as to whether we can know anything.

If no other conception of matter is possible than that it consists of distinct physical units—and no other conception has been formulated which does not blur what are otherwise clear and definite outlines—if it is certain, as it is, that vibrations travel through space which cannot be propagated by matter, the two foundations of physical theory are well and truly laid. It may be granted that we have not yet framed a consistent image either of the nature of the atoms or of the ether in which they exist; but I have tried to show that in spite of the tentative nature of some of our theories, in spite of many outstanding difficulties, the atomic theory unifies so many facts, simplifies so much that is complicated, that we have a right to insist—at all events till an equally intelligible rival hypothesis is produced—that the main structure of our theory is true; that atoms are not merely helps to puzzled mathematicians, but physical realities.

THE AIMS AND PURPOSES OF MODERN WORK IN BIOLOGY.

BY FRANKLIN W. BARROWS.
Instructor in Biology, Central High School, Buffalo, N. Y.

(Concluded from page 190.)

The motive for this delicate and painstaking work may be described as the quest for the secret of heredity, and for those elements or objects in the egg and the sperm-cell respectively which carry the qualities of the parent down to the offspring. Omitting now all mention of early theories of heredity, let us see to what position the biologists had attained in 1878, when Huxley said: "It is conceivable and indeed probable, that every part of the adult contains molecules derived both from the male and from the female parent; and that, regarded as a mass of molecules, the entire organism may be compared to a web, of which the warp is derived from the female and the woof from the male." While the researches of the past twenty years tend to confirm this view, they have not brought us much nearer to the actual secret of development, although they have piled up an enormous mass of details and added one theory of heredity to another. The limits of this paper will not allow even the mention of the half dozen theories that have been advanced by as many leading scientists. Somewhere in the complex and intricate architecture of the living cell, undiscerned as yet by the best microscopes, eluding every test that ingenuity has devised, lurk the secrets of development and heredity and no one can declare that we are not about as far astray in our search for these secrets as were the embryologists of a century ago. But the modern biologists have really witnessed what was never seen before,—the actual division of the egg and the multiplication of germ cells and the building up of the embryo. They have learned much as to the processes involved, little as to the forces and the factors in these processes.

The last few years have seen the most novel and sensational lines of experiment in the whole history of biology,—the work in experimental embryology, much of which has been done in America. Experimenters have succeeded in separating the cells of the

growing egg and rearing complete embryos from half or a quarter of an egg,—that is to say, they have isolated the cells in the 4-cell stage of development and produced an entire embryo from one of these cells. The most striking results in experimental embryology are reported by Professor Loeb of the University of Chicago, who has succeeded in developing the eggs of sea urchins without fertilization by the spermatozoa, through the action of a solution of magnesium chloride. It is unnecessary to add that such discoveries as these produce consternation and confusion among the adherents to certain cunningly devised embryological theories. We cannot predict how soon the experimental embryologists may produce other freaks in their laboratories that shall make it necessary to revise and recast our scientific creeds. We know that the field for such experiment is great and the results are received with eager interest.

It was natural that the embryologists should engage in the most painstaking investigation of the structure and composition of the egg. And by a natural extension of this careful study to the other cells of the plant or animal there has grown up the science of *cytology,* or the study of the cell in all its stages and phases of activity. At present the chief interests of the cytologists center about two problems, viz., cell division, and the structure of protoplasm, the living substance of the cell. It seems likely that the minute study of the cell will be insisted upon in the future to supply the basis of a rational physiology. One of our leading German physiologists, Verworn, reiterates the idea that our future advance in physiology must be along the lines of cell-physiology. In most of our physiological laboratories the investigation of the living cell, and of the unicellular animals and plants is demanding increased interest.

The mere suggestion of physiology calls to our mind a long list of brilliant achievements to the credit of the past century and suggests many lines of present experiment and research. It suggests also that horrible bugbear of vivisection. There were vivisectors and experimental physiologists many years ago, but two discoveries of the last quarter century,—anaesthetics and antiseptic surgery,—have added vastly to the possible range of humane experimentation on animals, and have led to an extension

of work along these lines that has excited considerable alarm and bitter opposition on the part of a non-scientific and hyperaesthetic public. Very much beneficent work has been accomplished by the experimental physiologist,—especially in lines closely related to medicine and bacteriology,—but very much more remains to be done by future experimenters. Verworn tells us that in the future we shall see experiments in physiology bearing on the problems of descent and extending the discussions of the mechanism of heredity beyond present bounds into the domain of physiology. Another and a very different physiological problem, "the old riddle of the causal relations between body and mind," to quote the same author, "remains apparently wholly untouched by natural science." The physiologist of the future may, moreover, be able to tackle the knotty "problems of cerebral mechanics" which are today unapproachable.

So much for what we may call ultimate aims of animal physiology. There are many other objects more easily attainable by the study of living animals, a few of which are excellently expressed by Dr. Conklin, of the University of Pennsylvania.* He says:

> The usual laboratory work in zoölogy, viz., the anatomy of a few alcoholic specimens, is less than one-half of the science and in all respects the least interesting and important half. Research today is tending more and more to the study of *living* things, and in this respect, as in so many others, research points out the way for advances in teaching. The study of living animals; of their actual development under normal and experimentally altered conditions; of their food and the manner of getting it; their enemies and friends, parasites and messmates; their mating, breeding, and care of young; the effects of isolation, crossing and close breeding on structure and habits; the effects of varying light, color, temperature, density of medium, etc., on color, size and structure of every part; the daily and nightly activities of animals; the origin and nature of peculiar habits and instincts—in short, the study of all the varied ways in which animals live and adapt themselves to their environment, is an integral part of zoölogy, and who can doubt that together these things form its most important part, and yet there are few if any places where any systematic attempt is made to give instruction in these subjects.

It is encouraging to see just such work as Dr. Conklin advocates becoming more common every year, and forming a large

*Science, IX, p. 83, January 20, 1899.

part of the activity of biological stations and experimental farms, while in some of our universities, notably the University of Pennsylvania, it enters largely into the work of the student and investigator.

In speaking of physiology, we are prone to overlook that division known as plant physiology; and no wonder, for we are told that it is scarcely ten years since this subject began to receive any considerable attention in this country, although it has been cultivated in Germany and other countries for many more years. The present progress of vegetable physiology is full of promise, however. Its many bearings on the important economic aspects of agriculture and forestry are now recognized. Special problems that await investigation refer particularly to ecology, root-absorption, and chief of all, the *constitution of living matter.**

No other branch of biology is so much the creation of the last twenty years as bacteriology. Its achievements, under Pasteur, Koch, and many others, are more or less known to all intelligent people, and its popularity as a study was such that for a time all other European laboratories were well nigh forsaken by the rush of students into bacteriology. The possibilities of the science are but just beginning to be realized. It has not only saved the silk worm industries of France, but in the hands of the doctor the practical application of the teachings of bacteriology has saved hundreds of thousands of human lives. This science has found a useful field, also, in the industries of dairying, brewing, gardening, horticulture and the culture of fish and oysters. The aims and objects of bacteriology,—leagued with the science of pathology,—are nothing less than the complete revolutionizing of the conditions of human life. If such a claim appears to be a trifle extravagant, one needs only to review the progress of the past twenty-five years, and his faith in these two sciences will be abundantly renewed.

An adequate appreciation of the science of pathology ranks it under biology, although it is too often thought of as a part of the medical course. It is entirely outside the province of such a paper as this, however, to attempt to point out the numerous lines along which present investigations are advancing. It must suf-

*Science X p. 245. Sept. 8, '99. Prof. C. R. Barnes.

fice to allude to the recent interest in tropical diseases, which has led to the founding of institutes and the establishing of Commissions in this country and in England, and especially to the interesting studies during the past few years on the mosquito in its relation to diseases of man and the lower animals.

In this brief review of the biologic field it seems evident that the old line between pure science and applied science is becoming obsolete; at any rate we hear less of this distinction and we find a disposition on the part of most biologists to be of use to somebody. This disposition is fostered by our government, which employs 6,000 scientific men in its various bureaus, at an annual expense of ten million dollars. Almost every first-class college and university in the country, it is said, is doing some kind of scientific work for the United States government. Most of the states give employment to a few investigators. Taken all in all, there is an encouraging demand for practical biological work by those who are competent to carry it on. One leading biologist is studying the oyster industry of Maryland; another is propagating eastern oysters in Oregon for the U. S. Fish Commission; a college professor in New York state is studying the annelids of Porto Rico for the United States government; several men in the interior states are studying the fishes of the Great Lakes and their food supply, directed by the head professor of zoölogy at Ann Arbor. The department of botany in the State University of Nebraska is carrying on investigations for the United States government into the forest conditions of the plains. We all know something of the services rendered to the government by Dr. Jordan, the distinguished President of Stanford University, who has devoted much time to the work of the U. S. Seal Commission.

Apart from these *practical* scientists, there is still, to be sure, a lessening minority of trained biologists, who lurk in laboratories and museums and engage in what they are pleased to call researches in *pure science*. These are our biological pharisees, who treat the publicans and sinners with considerable arrogance. But most investigators realize more and more clearly that, as Dr. Hodge says, "The human values attaching to knowledge are so enormous that we have no measures or terms with which to adequately express them"; and again, that "we may not be able to

estimate the value of truth until it be discovered, and that the investigator himself, who is willing to devote his time and energies to the work, should be the one to estimate its values." Viewed in this light, all new truth becomes valuable and no one shall say what intensely practical application may follow closely upon the next biological discovery.

Never has the argument for scientific investigation been stated more clearly and forcibly than by the late Professor Rowland of Johns Hopkins University, a physicist, speaking to the Physical Society of America. He said*:

An only child, a beloved wife, lies on a bed of illness. The physician says that the disease is mortal; a minute plant called a microbe has obtained entrance into the body and is growing at the expense of its tissues, forming deadly poisons in the blood or destroying some vital organ. The physician looks on without being able to do anything. Daily he comes and notes the failing strength of his patient and daily the patient goes downward until he rests in his grave. But why has the physician allowed this? Can we doubt that there is a remedy which shall kill the microbe or neutralize its poison? Why, then, has he not used it? He is employed to cure but has failed. His bill we cheerfully pay because he has done his best and given a chance of cure. The answer is *ignorance*. The remedy is yet unknown. The physician is waiting for others to discover it, or perhaps is experimenting in a crude and unscientific manner to find it. Is not the inference correct, then, that the world has been paying the wrong class of men? Would not this ignorance have been dispelled had the proper money been used in the past to dispel it? Such deaths some people consider an act of God. What blasphemy to attribute to God that which is due to our own and our ancestors' selfishness in not founding institutions for medical research in sufficient number and with sufficient means to discover the truth! Such deaths are murder. Thus the present generation suffers for the sins of the past and we die because our ancestors dissipated their wealth in armies and navies, in the foolish pomp and circumstance of society, and neglected to provide us with a knowledge of natural laws. In this sense they were the murderers and robbers of future generations of unborn millions and have made the world a charnel house and place of mourning where peace and happiness might have been. Only their ignorance of what they were doing can be their excuse, but this excuse puts them in the class of boors and savages who act according to selfish desire and not to reason and to the calls of duty. Let the present generation take warning that this reproach be not cast on it, for it cannot plead ignorance in this respect.

This illustration from the department of medicine I have given because

*Science, X, p. 832, December 8, 1899.

it appeals to all. But all the sciences are linked together and must advance in concert. The human body is a chemical and physical problem, and these sciences must advance before we can conquer disease. * * *

Where, then, are the greatest laboratories of research in this city, in this country, nay, in the world? * * * Where in the world is the institute of pure research in any department of science with an income of $100,-000,000 per year? Where can the discoverer in pure science earn more than the wages of a day laborer or cook? But $100,000,000 per year is but the price of an army or a navy designed to kill other people. Just think of it, that one per cent. of this sum seems to most people too great to save our children and descendants from misery and even death!

If we ask now what is the spirit of the modern biology, we shall find that the workers are striving to serve mankind, to subdue the animal and vegetable kingdoms and to create more favorable conditions for human progress. Shaler and Hodge have recently shown us that out of the millions of species of plants and animals, we have as yet named and classified only the insignificant sum of 500,000. Of these we have learned to use in various ways not more than 1,000 animals and 1,000 plants. The other species are before us, presenting problems enough for centuries of study and destined sometime to become resources of enormous value. The control of these living forces is as worthy a task as the utilizing of tidal energy or the harnessing of Niagara. Just at present we are devoting our inquiries principally to the control of the bacteria and the insects.

Our sketch of the present aims of biology would be incomplete without an allusion to the intense interest manifested today in the popularizing of all biological subjects. This is evidenced by the phenomenal increase in the number of attractive books and magazine articles gotten out during the last few years for non-scientific readers. Many biologists of acknowledged authority have aided in the preparation of such books, while others, equally eminent, have gone aside from their regular work to prepare elementary text-books to take the place of older and less trustworthy authors. Even the nature study of our primary schools has engaged the earnest attention of some of our university professors, who have written articles, in a truly scientific spirit, for the children and for their teachers.

We may discern several motives for this kind of popularizing

work on the part of earnest biologists. Sometimes it is a spirit of protest against the flood of cheap shoddy which finds its way into the literary market and the schools under the guise of science, and which is much worse than no science at all. Usually, however, the authority in biology, when he addresses himself to the popular mind or to the child, does so under the profound conviction that modern society needs those lessons in altruism which can be best taught by teaching the unity of all life and of nature; or perhaps he looks on biology as of incalculable value in an economic or sociological sense, as one of the forces that is to help humanity. In any case, we pay our respects to the scholar or philosopher who brings the popular mind into closer sympathy with plants and animals. Such labors are no less fruitful than those of the investigator and discoverer.

RECENT ADVANCES IN THE PHYSICS OF WATER.

BY GEORGE FLOWERS STRADLING, PH. D.

(Continued from page 212.)

Röntgen predicts that "the viscosity of water at high pressures will be less reduced by a given increase of pressure than at low pressures," and also that the effect of pressure in reducing the viscosity will be greater the lower the temperature of the water. In both cases his anticipations have been confirmed experimentally by R. Cohen* and L. Hausser.†

Following the road marked out by Röntgen, a number of investigators have succeeded in finding the explanation of some of the irregularities of water which he did not discuss. Hugo Witt* of Stockholm has applied the theory to several phenomena of aqueous solutions. From the equation of equilibrium between the two kinds of water molecules in an aqueous solution he infers that the presence of the solute has the effect of causing some of

*Phil. Mag., L., 460 (1900).
†Drude's Ann., II., 1.
*Zeitschr, f. phys. Chem., xxxv., 77.

the ice molecules to change into those of the second kind. This at once explains why the volume of an aqueous solution is generally less than the sum of the volumes of the water and of the dissolved substance. The contraction is the result of the change of molecules of greater specific volume into those of less.

We have seen that an increase of pressure lowers the temperature of maximum density of water. Now both pressure and the presence of a substance in solution have the effect of reducing the number of ice molecules, and hence it appears why the temperature of maximum density of an aqueous solution is below 4° C.

Witt explains the high specific heat of water as due to the heat required to change ice molecules into those of the second kind. Solutions in water commonly have a lower specific heat than water alone. Even after making allowance for the solute, whose specific heat is less than that of water, it is found that the water in the solution seems to have a less specific heat than before the substance was dissolved in it. This is attributed to the solution having fewer ice molecules than water, so that a rise of temperature of 1° will cause the transformation of fewer of these and will therefore require a smaller addition of heat. He finds in the heat requisite to bring about the change of ice molecules into the other form a reason why the solution of substances in water is usually accompanied by a lowering of temperature.

Within the past year there has appeared a paper by Sutherland* in which the author endeavors to furnish a quantitative explanation of the behavior of water. He aims to show that steam is H_2O, ice $(H_2O)_3$ and water a mixture of H_2O and of $(H_2O)_3$. He calls H_2O *hydrol*, $(H_2O)_2$ *dihydrol*, and $(H_2O)_3$ *trihydrol*. According to this nomenclature Röntgen's ice molecules are trihydrol and his molecules of the second kind are dihydrol.

The method of determining the density of dihydrol at 0° C. is here given to serve as an example of Sutherland's manner of procedure. A curve is plotted in which the ordinates are the densities of water and the abscissas the corresponding temperatures. The curve has its maximum ordinate at 4° C., then sinks

*Phil Mag., L., 460 (1900).

toward the axis of X and appears to approach a straight line asymptotically. It seems reasonable to take this straight line as giving the density-temperature relations of one of the ingredients of ordinary water, of dihydrol, as is shown later. Following this line back until it meets the axis of Y, the density at 0° is read off as 1.083.

Mendeleeff has calculated an equation giving the density of water as a function of the temperature. The investigator throws this equation into a form in which the density is the sum of five terms. Let us now call water at 4° C., made up as is supposed of two constituents, the standard mixture. Water at any other temperature may be regarded as formed by uniting a mass of the standard mixture with a mass of dihydrol. Let the further assumption be made that both of these in expanding follow the simple law,—$\rho = \rho_0 \, (1 - k\,t)$, where

$$\rho_t = \text{density at } t^0$$
$$\rho_0 = \text{density at } 0^0$$
$$k = \text{constant.}$$

Now it is possible to calculate the density of water at any temperature upon the above suppositions and to throw the result into a form which can be compared with Mendeleeff's formula. From the comparison of the two formulas it follows that the density of dihydrol at 0° C. is 1.08942, a result agreeing well with the value 1.083 obtained graphically as explained above.

It will not escape notice how much this conclusion rests upon assumptions. The reason for believing the constituent considered to be dihydrol will be given when surface tension is discussed.

The following values are given for the fractional part by weight of trihydrol in water at different temperatures, under 1 atmosphere and 150 atmospheres respectively:

	Temp.	0°	20°	40°	60°	80°	100°	120°	140°	198°
Trihydrol at	1 atmos.	0.375	0.321	0.284	0.255	0.234	0.217	0.203	0.191	0.165
	150 atmos.	0.351	0.300	0.264	0.237	0.217	0.203	—		

It is calculated that at 2300 atmospheres the whole of the trihydrol in water is changed into dihydrol at 0° C.

(*To be continued.*)

THE PLACE OF FIELD WORK IN HIGH SCHOOL PHYSIOGRAPHY.

BY C. W. GOODRICH.

Instructor in Physiography, Holyoke (Mass.) High School.

In speaking of the place of field work in a high-school course in physiography it is not necessary to show that it deserves a place, but the question is to determine how important it is and in what manner it can be carried out best. The matter of field work is a serious one for physiography teachers to contemplate, and is too often neglected because it means additional hours of work for the teachers. It means, however, increased interest on the part of the pupils and therefore a more rapid advance in class-room work.

The chief value of field work arises from the fact that the student comes directly into contact with the physiographic forms that he is studying about, and a form once seen is sure to be remembered much longer than one where the mental picture alone is relied upon. The latter is usually a mere hazy notion, if, indeed, any is retained at all. It is difficult to have pupils realize the extent to which the ever-acting agencies of nature are to be noted, if the opportunity to note these changes is neglected entirely. As an example, suppose one were to show a class an embankment without any vegetation upon it before and after a rain. The changes noted upon it are merely those taking place during every storm, and yet many of the typical geographical forms can be noted on it in miniature. The effect of the rain in washing out the roads might also be taken as an example of erosion of simple type.

It matters not whether the teacher is located on coast, plain or mountainous area, simple ways of illustrating the ever-acting forces of nature are always at hand, varying in kind and amount, however, with the locality. The type of field work so far mentioned, that is, explanatory and demonstrative, is just as well fitted for pupils in the lower grades as for those in the high school. This type of field work is such as may be taken up first in the study of physiography with profit, as it results in a clearer understanding on the part of the pupils. I am here supposing that

the lands are given first attention in such a course, as there is something in the study of the lands which appeals to pupils more strongly than does the ocean or the atmosphere.

Such field work as described above serves to illustrate the text-book, but it should be regarded as nature's text-book from which our text-book information is drawn. After the first of these field trips the attempt should be to draw out the pupils, that is, to lead them to make their own observations and to have them reason out the cause from the effect noted. If the pupils are without any training of this character, the progress at first will be slow, but if a little care be taken in the introductory trips the teacher will soon find that there is no end to the questions which will arise. A written report of a trip should be required, not merely as an indication of work done, but in order that the teacher may find out those pupils who have greater difficulties than some of the others. If the report is not required, there still remains a certain value from the trip, but one of the results of the report is that it fixes in the mind of the pupil that which has been explained to him and which, by writing, he has in turn shown himself capable of explaining. As soon as the pupils have gained the power of observation well, ask them questions in the field which they are to answer in their reports and encourage them to make drawings of the forms seen.

There is, however, a higher type of field work of even greater value to the pupil, that is, where a small locality is chosen and a map made of it. This work requires close attention on the part of the teacher and also much assistance from him at first. The locality should be chosen with care, as it is not the making of the map which is to be the end sought for, but it is the better and clearer understanding of how some of the smaller features of the locality have been produced. This kind of work comes best in the spring after the pupil is familiar with the general land forms and the ways in which they are produced. Even then it will be found profitable to cover the field at first in one trip with the class and then to spend more time on a closer study in which the pupils gain as much as possible for themselves, but any questions should be answered for them or they should be led to see for themselves what the answer is. In following out this plan, a preliminary or

general report should be written first, which tells what is to be studied later, and then a more definite description comprising work of later trips as well as a map and sections where they are needed. This is the plan on which the appended report is made out. It comprises the field work of two first-year pupils of the high school who worked together in one of my classes, and it may be taken as a fair sample of what can be done on trips of this nature. The work is illustrated by three photographs, the locality of which is shown on the map.

Let us look to see how much time should be spent on such work. If the field work is of the type first described, an afternoon a week should be spent in the field as long as the open weather lasts in the fall of the year. Allowance should be made to the pupil by giving him his class period for study either on the day on which he goes into the field or on the day after. In the first case it is designed as a chance to get the next day's lessons and in the second place as a means of diminishing the work of the next day.

In the second half year, devote if possible two afternoons a week to field work, preferably of the second type, at least during April and May, if the weather will allow, as the warm days of June take away the interest of such a trip, as it is then too warm for much walking, and also as the last few weeks of school require more of the teacher's time in assisting backward pupils.

The objection may be raised that the amount of time here specified can not be given by every teacher. This may be true in certain cases, but it is well to have as a motto—As much field work as possible and the more the better. It is, then, the only way to teach properly the subject of physiography, and no teacher can plead as an excuse the lack of means of illustration, as such an excuse is merely an indication of poor preparation on his part. Field work is entirely within the reach of the grade teacher as well as the high-school teacher. The work, then, should commence in the lower grades and should lead up to and prepare the way for more advanced work in the high school in just the same manner as the work of the high school should fit for the college. Let every teacher devote as much time as possible to field work, preferably that of the type mentioned for the latter half year, but

let no one do away with field work completely, as a little is better than none at all.

The following report is entirely the work of two pupils in the first year of the high school of Holyoke, Massachusetts. A few corrections in expression have been made, but the thought and the map, as well as the sections are of their own making. The photographs illustrate well the description of the parts of the brook as found in the following report:

THE WHITING STREET BROOK.

GENERAL DESCRIPTION.

The Whiting Street Brook was taken as the point of study on one of our field excursions. This brook is one of the small tributaries of the Connecticut river. Its general course is very meandering.

Near the mouth of the stream the rock is sandstone, as is also the bed. The edges of this rock are rough and uneven, with large crevices visible. This, with the slope of the land, causes numerous rapids. Owing to the hardness of the rock the stream has not been as active in cutting through it as through the glacial deposits above. Another cause of this lack of cutting is the tilt of the rock, which is here dipping the same way that the brook is flowing, that is, roughly northwest to southeast. The course of the brook has a steep slope and this, with the cause mentioned above, tends to produce a youthful or V-shaped valley. A short distance from its mouth the rock changes from sandstone to trap. The brook here does not have such jagged edges to flow over, because this kind of rock is not in layers, and can easily be rounded by the water. Another agent aiding the rounded appearance is the moss with which the rock is covered. A reason for the rapid decay of this trap rock is that the water forces its way into the joints, making the rock break in layers. The boulders in this stream produce small falls or rapids, at the base of which are pools.

In this place the valley is changing from a youthful to a more mature stage. Above here is a small temporary base-level, due to the trunk of a large tree which had fallen across its course and had also collected sediments behind it. This made the brook turn from its straight course, more to the left.

Nearer the source a small oxbow cutoff was visible. Here the rock changed back to sandstone again, the result of which caused the valley to become more mature than below. Where the bed was pebbly, the brook had cut very little, making the valley nearly level. In one place at least five courses were cut. The changing of one course was due to the root of a tree which had grown across the stream. Here also the sediments of shale and sandstone fragments were noticeable. They were deposited

upon the convex bank. Above here the rocks were tilted by the forcing upward of the lava sheet of which Mt. Tom is the remnant. The tilt is about 25 degrees to the east, making the strike north and south. The brook has flowed down the dip of the rock. A little above here a large pile of sediment was found.

As we followed along the bed of this stream, which was tilted standstone, we reached the dam of the small reservoir which has been built across the stream, thus ending the brook in its natural state.

DEFINITE DESCRIPTION.

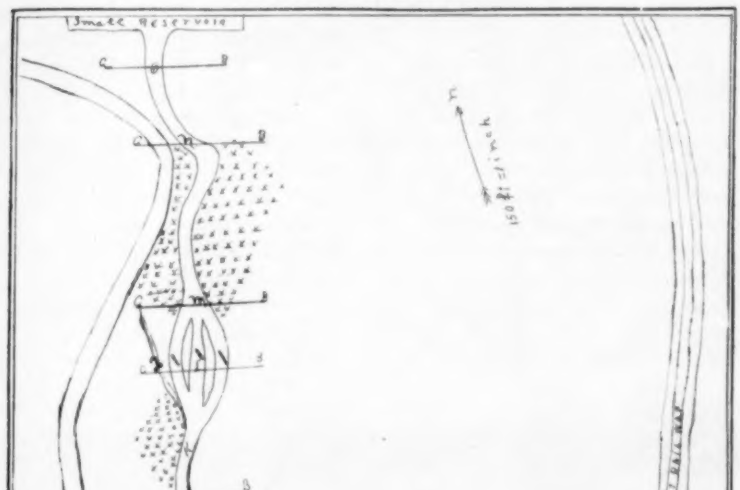

Fig. 1.

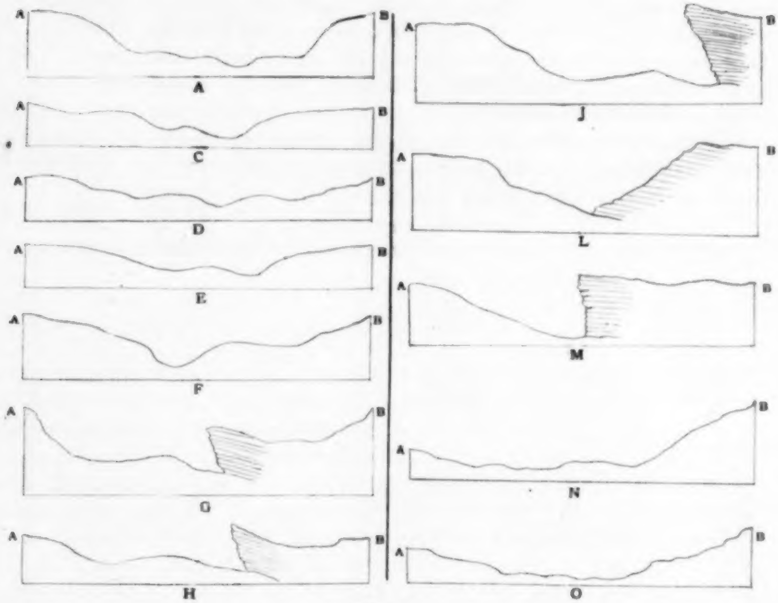

Fig. 2.

Our first stop was at (A). Two distinct courses were seen. The deepest of which was the one the brook occupies at present, and upon the map is (1). The next older is (2). In this, water is still to be found, but it is stagnant. (3) is still an older course. Here the land is marshy, but no water is present in the course. This marsh indicates that not long ago the brook occupied that course. (4) is the next older, while (5) is the oldest of all.

The bed of course (1), is composed of trap boulders, also fragments of sedimentary rock, but the latter are not as numerous as the former. These fragments are composed of shale, small pebbles of quartz, also pieces of feldspar and granite which have been brought down from above by the water.

The young or V-shaped valley is changing to one more mature. Here the descent is comparatively steep, causing many rapids. At the base of one of these a small pool still containing water may be seen.

In order to find the cause for the changing of course (5), as mentioned in (A), we stopped at the left bank of the brook at (B). The large root of a tree had grown across the channel of the stream. In this course (5) were seen small pools left there from the time the course was occupied.

The valley at (C) is more U-shaped or mature than below. Here the rock changes from trap to sedimentary, although boulders of the former may still be found.

There are three distinct courses on the left side of the brook at (4). The oldest of the three is (4); the next in age is (3); (2) is still younger, while (1) is occupied by the stream at present. The rocks in the bed are of more uniform size, being broken in large layers.

At (E) a stone wall was built across the brook, causing it to flow in two directions; (1A) flowing through the opening made for it; (1B) washed away some of the rocks of which this wall was constructed and then flowed on as tranquil as ever. The bed was very rocky and many boulders were seen. At the right of this stream is an old course now unoccupied. It is as low as, if not lower than, the present course, and is indicated as (2) upon the map.

At (F) the brook is running through a meadow. Course (1A), as mentioned in (E), flows along the left side of the stone wall, while (1B) does likewise upon the right. The bed is grassy and pebbly with sedimentary rock beneath. The brook flows away from the stone wall at (G), but the old bed continues the same. The stream has a marshy flood plain upon each side. At (H) the sedimentary rocks mentioned in (F) are now upon the surface. This sandstone dips about 25 degrees to the east. The strike was north and south. The brook flowed along this dip until the level of the meadow was reached. In one particular place the brook has so worn the rock as to form a large overhanging wall. The weathering of this wall is aided by the moss and other organic agencies growing in the crevices; the joints also aid by allowing the water to flow through them.

Fig. 3.

Locality H on map looking upstream, showing where the brook is cutting under the dip of the sandstone layers.

At (I) above the bend in the brook the rocks are softer than below. A small waterfall with its corresponding pool met our view. Because of the softness of the rock the water had so worn it that the dip could not be seen.

The rocks at (J) are harder than at (I), and also tilted at a less degree, and the former allowed the dip to be seen. The difference in hardness of the rock caused the brook to meander. The parallel jointings are plainly visible. They are about north and south, east and west, also northwest and southeast. The broken fragments again formed rapids in the course.

At (K) the large stump of a tree caused the stream to change its course more to the right. At high water this stump causes a waterfall, but now it is dry. In the small pool below is collected a pile of fine sediments. The direction of the jointing here is about southwest and northeast, also northwest and southeast.

Above (K) a portion of the rock is broken along the joint very smoothly. The sedimentary layers are dipping about 15 degrees to the east. Small pebbles are found in the bed. Upon the right side is a small marsh, also an old course.

At (L) a small side stream is seen to enter the main brook upon the left. This tributary contains water only in the Spring. The main brook has divided into three distinct courses, all occupied. The greatest amount of water is carried in the middle course. It is very marshy upon both sides of the stream. Upon the left side is a large accumulation of sediments, washed down by the water, from the road which is above.

From (G) to (N) the large hanging wall upon the right is very noticeable. The jointings of the rock in this wall are parallel.

A large pile of boulders were seen at (M). During high water they form a waterfall, but it is dry at present. Below this fall is a small water area or pool, within the center of which is a large accumulation of sediment. Here the bed is nearly level, that is, the sandstone of which the bed is composed has only two joints or breaks to mar its smoothness. A large crevice is noticeable in the hanging wall. In the joints of the crevices moss, ferns and flowers were growing which aided in the decay. The rapid weathering of this wall caused the wide valley at this place, while the depth was due to the slope of the land and the force of the water. In some places the jointing was at right angles. One large boulder and several smaller ones were found upon the left bank of the stream at (N). The former caused the stream to divide and flow upon each side of it. It also had caused the brook to deposit the large pile of sediment collected behind it. The jointing was parallel and also at right angles. Owing to the lack of force of the water, a large pile of sediment was deposited, the coarsest near each shore. At the center it was fine sand. If this was consolidated, it would be called conglomerate. For a short distance beyond this point, at (N), the brook flows parallel with the road. The third picture (Fig. 5) describes the view, looking down

Fig. 4.
Looking upstream from a point above M, showing the long descent to the pool at M.

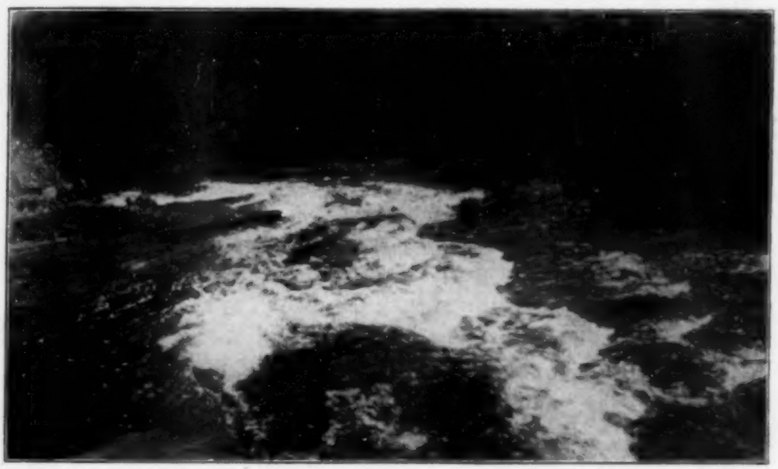

Fig. 5.
Looking downstream, showing the sediments accumulated in the pool in the background.

stream to the deposit of sediment mentioned above. The second picture (Fig. 4) looks up stream from the foot of the long slope, which begins near this deposit of sediment, shown on the third picture, and takes in the pool at the base of the slope.

At (o) the valley seems to be a small meadow or marsh, due to the softness of the rock. Owing to this marsh there is a very abrupt curve or bend in the course below. The bed is grassy and the valley nearly

level at the source of the natural brook; that is, when we come to the dam of the small reservoir.

The Connecticut river from a point a short distance below Smith's ferry to the Canoe Clubhouse at Holyoke is acting just like the brook which has been described above. It is flowing along the strike and down the dip of the red sandstone layers. This portion of the river is known as the rapids and the bank on the western side dips gently into the stream and is formed of strata of sandstone. The peculiar jointing causes the rock to break into large slabs and the water coming in contact with the broken edges forms numerous whirls and eddies. On the other side of the river the edges of the tilted sandstone layers form a nearly vertical wall. The water off this bank is also deeper, as is also the case in the brook. The river here, owing to the slope, is actively cutting, but it is hindered in its action by the character of the rocks, which, while soft, have resistance enough to make the rate of down cutting a slow one. In a word, the brook and the river show the same features, only one is on a smaller scale than the other.

AN EXPERIMENT WITH ROGET'S SPIRAL.

BY C. F. ADAMS.
Instructor in Physics, Detroit Central High School.

Roget's experiment, as is well known, consists of a spiral coil or spring suspended vertically, so that its lower end just touches some mercury placed beneath. When an electric current is sent through the spring the mutual attractions of the several spirals shorten the spring, and thus break the circuit at the surface of the mercury; the attraction then ceases, and the spring lengthens by its own weight, thus re-establishing the circuit and causing a repetition of the motion. In this way a vibratory motion is maintained in the spring. While experimenting some time since with such a spring, I noticed a tendency toward the formation of a node near the lower end of the spring. This led me to experiment upon different springs of various dimensions and degrees of flexibility. The chief difficulty I met with was in establishing a simple vibratory motion, two or more rates of vibration usually combining in the spring to form a complex motion and thus obscuring the nodes.

One spring was made of No. 20 spring brass wire and was

about 2 cm. in diameter and 66 cm. long. In this spring a node was easily established at a point about 22 cm. from its lower end, while between that point and the upper end there was considerable amplitude of vibration. A strong current was necessary to maintain the vibration, five or six secondary cells being used, and very careful adjustment of the contact with the mercury was necessary.

Recently this experiment has been modified and more striking results have been obtained. A more slender spring has been used, one made of No. 22 wire about 2.5 cm. in diameter and a meter long when suspended, the spirals being about 5 mm. apart. The lower end of the spring was fastened to the hammer-rod of an electric bell, which was placed in such a position as to cause longitudinal vibrations in the spring. It was necessary to load the vibrator to reduce its rate of vibration; also to limit its amplitude by stops. One or two cells are sufficient to maintain the motion. With such an arrangement the number of nodes and antinodes maintained in the spring can be varied, the number depending on the adjustment of the vibrator. In the spring here described at times there were 10 nodes, sometimes 13, and again 15 nodes were maintained. At each node a single spiral of wire was almost perfectly stationary, while between the nodes there was a wide amplitude of vibration. The motion is striking and beautiful. It could easily be projected by a lantern on a screen.

This experiment is the counterpart of the familiar one with a rope, except that we have here longitudinal vibrations in an elastic medium, instead of transverse vibrations. It is especially interesting because it illustrates so perfectly the motion of the air in vibrating air-columns.

APPARATUS FOR EXPERIMENTS IN ELECTROLYSIS.

BY WARREN RUFUS SMITH.

Department of Chemistry, Lewis Institute, Chicago.

In Fig. 1 (No. 1) is shown an apparatus which has given good results in the hands of students. It is simple in construction and is made from materials which are obtainable from any electrical supply house. It is designed for use with the ordinary 110

volt lighting current. The details of construction are as follows:

The connection with the circuit is made with two brass plugs furnished with insulating handles. In many cases it would be found more convenient to replace these plugs by an ordinary screw attachment plug. To these plugs there is attached a piece of two-strand incandescent lamp cord leading to a block of wood. On the block are two binding posts and an incadescent lamp socket. One strand of the cord goes directly to the foot of one binding post and the other strand goes to the lamp socket and thence to the other post. To these binding posts is attached another piece of two-strand lamp cord terminating in two electrodes. These electrodes are made from coppered arc light carbons. One end of the carbon is fitted with a brass cap holding a screw carrying a nut and washer as shown in the detail drawing (No. 3). This cap

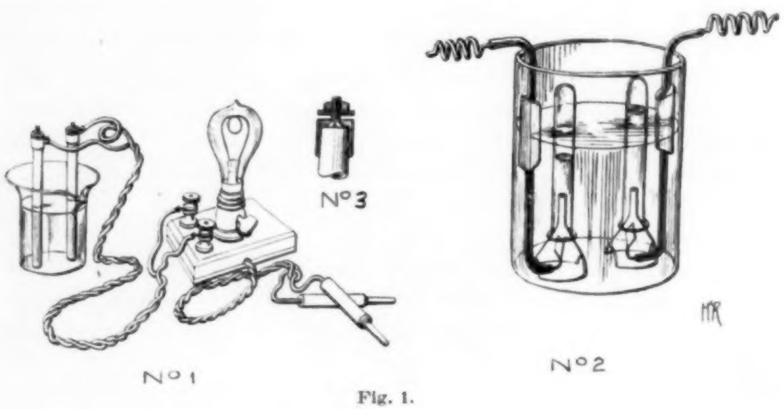

Fig. 1.

is soldered firmly to the carbon. This method of attachment allows the easy renewal of the carbon in case it is broken. The carbons are dipped in nitric acid to remove the copper coating and after washing are ready for use. The advantages of the lamp in the circuit are threefold. It serves as resistance, as a switch, and as a galvanometer. There are no bare wires or connections back of the lamp, hence it is impossible to get a short circuit with this arrangement so long as the insulation is unimpaired. The carbons

may touch without doing any damage and the shocks which students may get by handling them are harmless. Whenever desired, the lamp can be turned off, and then one electrode is "dead" and no current passes. Of course one electrode is always "live" when the apparatus is connected to the circuit, but the shock obtainable by grounding that is slight. The brightness of the lamp shows the amount of current, and hence the conductivity of the electrolyte. Results obtained in this way are always rough and only comparative at the best. However, they are sufficiently marked to illustrate many facts and principles, for example, the increase of conductivity with dilution.

The apparatus described above, while serving admirably for many experiments, is not suitable for those in which it is desired to collect the gases evolved. Fig. 1 (No. 2) shows a form of cell adapted to this purpose which can be made from ordinary laboratory material. The cell is a large battery jar. The electrodes are pieces of sheet platinum welded to short platinum wires. These wires are fused in the ends of glass tubes and are connected inside the tubes to ordinary copper wire.

This connection is made either by solder or by mercury. The glass tubes are bent, so that, starting from a point on the bottom of the jar midway between the center and the wall, they extend horizontally to the wall of the jar, then vertically up the wall, and finally horizontally over the edge. They are firmly attached to the walls by means of sealing wax. If the wires are connected by solder, the tubes should be bent and the wires connected and placed inside before the ends are fused around the platinum. If a mercury connection is to be used this is not necessary. Over each electrode there is placed a small short-necked funnel. The rim of the funnel is cut away slightly on opposite sides in order to allow the glass tube to pass on one side and to give a greater conductivity on the other. The cell is connected through the lamp to the lighting circuit as before. For use the cell is filled nearly full of liquid (e. g. dilute sulphuric acid) and test tubes are filled with the liquid and inverted over the necks of the funnels. The current is turned on and allowed to pass until sufficient gas has been collected. The current is then turned off and the gas tested or measured.

ELEMENTARY EXPERIMENTS IN OBSERVATIONAL ASTRONOMY.

BY GEORGE W. MYERS.

(*Continued from page 198.*)

Experiment VII.

To find the law connecting the distance of the observer with the apparent size of an object.

(a.) Place a globe, or other object, at a distance equal to 20 or more times its diameter, from the home-made plane table described above, and draw lines on the sheet of paper pinned to the board directed toward the opposite ends of a diameter, and measure the angle between them with a protractor. Then remove the globe to twice the former distance (at B) from the table and measure the angle again, then to three times (at C) the distance, etc. Tabulate the distances in one column and the measured angle in an adjoining column. Can you discover the law connecting the distances and the measured angular diameters? (See Fig. 9.)

(b.) A very good crude transit can be made by graduating to degrees (or to any desired accuracy) the arc of a circle struck with a center at a point about half an inch from the middle of one edge of an inch oak board, planed smooth on one side and sawed to about two feet length. Bore a half-inch hole at the center of the arc, and cut out another board one foot square from inch stuff, and after surfacing it on one side, graduate it also to degrees about a point near (about 1¼ inches above one end) one corner. Screw an alidade arm pointed at one end, and carrying

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***For the convenience of those who may desire to use these experiments (there are forty-four of them) in their classes, they may be obtained in pamphlet form from "The School Science Press," Ravenswood, Chicago, at 25 cents a copy, and $2.50 a dozen.**

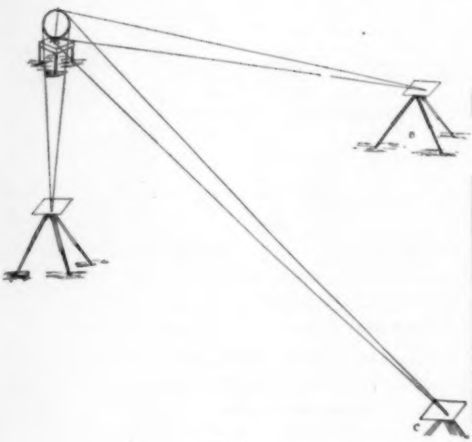

Fig. 9.

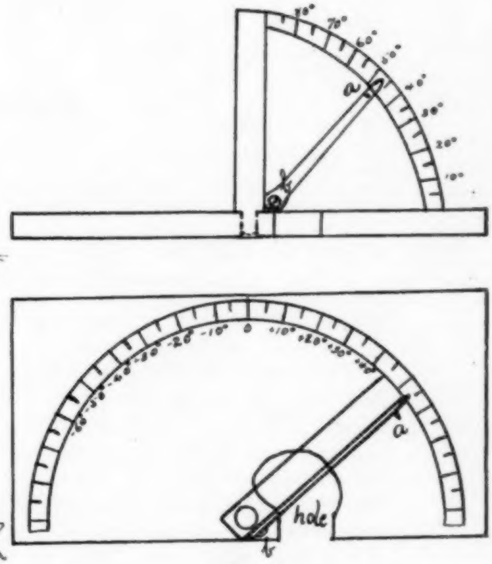

Fig. 10

sharpened nails for sights, to this board at the center of graduation. Then cutting a spindle on the lower edge of the square board, so as to fit the hole in the first board, set the former so that it may swing freely about a line perpendicular to the latter board. The alidade being now free to swing about the screw at the lower corner, the measurement of vertical angles is made possible. To use the transit, set it on the top of the plane table described above, and level up as was suggested for the plane table. (Fig. 10.)

Problem—Execute the experiment (a) with this transit.

(*To be continued.*)

Metrology.*

THE CENTENARY OF THE METRIC SYSTEM.

BY JACQUES BOYER, in *Revue Encyclopedique Larousse.*

Translated by DR. WILLIAM H. SEAMAN.

(*Continued from page 218.*)

The report of this commission was presented to the legislature on June 22, 1799, at the same time with a platinum measure forged by the metallurgist Jannetti. This date is therefore the beginning of the metric system. Representations of the new measures were used to familiarize the public with them, the system attracted the caricaturists, and carpenters and geometers published manuals intended to teach it in a short time. Among the curious literature we may cite a dialogue between a capitalist and a real estate agent, read by M. Framery before the Philotechnic Society, the first of Floreal in the year XIII. Its object was to present in comic aspect the shocking complexity of the old measures used in the most ordinary affairs of life, and to bring out the advantages of the metric system. We give a part of it. The subject is the purchase of a piece of real estate by an investor, who visits an agent, with whom the following conversation is held:

Investor. I wish to buy 200 or 300 arpents of vineyard.

Agent. Very good, sir. But since you use the old terms, how large will you have your arpents?

Inv. What do you mean by how large? Is not an arpent always 100 square rods?

Agent. Yes; but all rods are not the same length; they change in counties, sometimes in townships.

Inv. What! not in this borough of Paris!

Agent. Oh yes, in the same village even. For example, in Brie there is the rod of 18 feet; that is the most common. There is also one of 18 feet 4 inches, one of 19 feet 4 inches, of 20 feet and of 22 feet. At Belleville, at Charonné, at Charenton-Maurice, at Nogent, etc., there are two kinds of rods. There are three at Pantin, and five in the county of Vincennes; in fact, there are five kinds of rods in this department.

Inv. That is frightful. Is there no way out of this chaos?

Agent. It will be found by the establishing of new measures to which there is no opposition and which, referring everything to one invariable standard will secure everywhere the most desirable uniformity.

Inv. Truly you incline me to this system if I had time to study it. But now to our business. I want to be near the river.

Agent. I know of two plots of about 300 arpents, to speak your language, that would suit you; the area is nominally the same, but actually very different.

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*Communications for the Department of Metrology should be sent to Rufus P. Williams, Cambridge, Mass.

Inv. No matter, the price is undoubtedly according to the real size. Now, I would like to know exactly how much wine they will yield; for instance, just how many barrels did they make last year?

Agent. If you want to be precise, do not talk about barrels, they are never exact. Perhaps we shall understand each other if we use pints. But here we shall get lost if we stick to the old style. There is the pint of Saint Ouen of 47 cubic inches, and the pint of Nogent of 74.

Inv. Yes, that is what they call the measure of Saint Denis, but if there are five kinds of rods, there are only two pints.

Agent. Oh, you are mistaken. First, Saint Ouen has its pint of 47 cubic inches, and is close to Epinay, where it is 74, and then there is the Dubeaugey pint of 69, and the big chapter is 70 and the little chapter is 66. These may not be all in use, but in Bercy close to Faubourg Saint Antoine, they have three, one of 47, one of 74 and another of 79 cubic inches.

Inv. And how much grain will these plots grow?

Agent. That is easy to find out because except in Saint Denis the bushel is the same throughout the department of the Seine.

Inv. That is fortunate.

Agent. Grain is measured by the *muids*, equal to 12 septiers, each having two mines, and the mine has two minots, and the minot contains three bushels, then the bushel is divided into the half, the quarter, the eighth, and the liter, which is the sixteenth part, and which is also divided into halves, quarters, and eighths, and also the small measure, which is the sixteenth part of a liter.

Inv. But how can I keep all these in my head?

Agent. I don't know, since you are frightened at the twelve words that express the whole of the new system for every kind of weight and measure.

Inv. Well, let the bushel go. I want to have a little wood on my place. How much a year will the land you offer me cut?

Agent. That is according to the length of the sticks.

Inv. Why, the ordinary length, of course.

Agent. That is 42 inches in this department, but in Pierre-fitte the brigot, as they call it, varies from 24 to 30, and in Branches du Pont it is 48.

Inv. You will drive me crazy with your confusion of measures. How long do you suppose it will take to learn the new ones whose names even are not familiar?

Agent. If you were 15 or 16 years old a couple of days would suffice, but at your age, full of business and pleasure, if you will give an hour or two a day, I think it will take you about a week.

Now let us return to the serious history of the meter. Méchain at the beginning of the century proposed to extend the meridian to the Belearic islands instead of stopping at Barcelona. Since Dunkirk and Fromentera are situated equally distant from the mean parallel of 45 degrees, this would avoid any error arising from the flattening of the earth at the poles, and hence a more exact measure for the standard could be obtained. Unfortunately Méchain died of fatigue and fever before finishing his undertaking, and the Bureau of Longitudes charged Biot and Arago with its continuance. They ran many perils trying to push their triangulation into Africa, but they did not reckon on the pirates, who kept them prisoners many months. However, they did not lose the results of their work, and after a forced sojourn in Algiers, Arago landed at Marseilles on July 2, 1809. It was not deemed best to alter the meter of the archives already finished; the correction required by the new results would have been insignificant, and the system having been legally adopted on November 2, 1801, it would have caused complications.

Nevertheless, the old measures continued in use among the common people till the monarchy of July, when on June 12, 1837, the Marquis Laplace presented to the Chamber a report, which concluded by prescribing that from January 1, 1840, all weights and measures except those established by law and constituting the decimal system should be forbid-

den. From that time it became a part of our customary usage, and as it is said that in France everything ends by a ballad, we add some verses of a "Complaint of Our Weights and Measures," which was peddled around the Capital. The imitation will suffice to give an idea of this doggerel, which owes its interest entirely to the date of its appearance. Whether these trifles contributed to popularize the measures or not is difficult to say; anyhow the new system was adopted without difficulty, and for thirty years, like happy nations, the meter has had little history. But from the date of the Convention of 1875 it entered on a new phase, that of becoming an international standard.

HOW TO LEARN THE NEW MEASURES. PARIS: 1840.*

Lengths.

Now come, ye architects,
Whose brilliant ideas vex
Your souls, and hark to me.
No inches more shall be;
Just throw away your two-foot rules,
And take your meter with your tools.

Liquids.

The measures of the ancient sort,
By which we've often sold and bought—
The barrel, gallon, quart and gill—
Will never more their purpose fill.
You now must learn to use the liter;
For less, the cubic centimeter.

Weights.

Now we'll talk in kilos and grams;
No longer use the pounds and drams,
At least, if we're intelligent.
Those old weights are obsolescent.
Grams to a kilo one thousand require,
Kilos for tons the same I desire.
When the new method is well in hand,
And the old forgotten in our land,
All will wonder, in days then past,
Our barbarous system so long should last.

About the time the system was established in France it was also adopted by Belgium, the Low Countries, and Greece. In 1862 M. Eward persuaded the British Chamber of Commerce to inquire into its adoption by England. Shortly afterwards Italy, Switzerland, Greece, Belgium and France signed a monetary convention in 1865, and the next year the United States recognized legally the existence of the meter.

In 1867 the international character of the meter became more pronounced. The Academy of Sciences of St. Petersburg passed a resolution, approved by the Czar, in favor of the metric system, and at the same time the International Geodesic Commission adopted the following important resolution: "In order to define a common unit of measure for all European countries we recommend the construction of a new European prototype meter." "The length of this standard should differ as little as possible from the meter of the Archives, and in any case should be exactly com-

*This song was published by Escudier, 127 rue de Bac, Paris, 1840.

BIOT (1774-1862).
Facsimile of an engraving by Ambroise Tardieu.

Marquis de LA PLACE (1740-1827).
Facsimile of an engraving by Delaistre, after Guilliaminot.

pared with it. The construction of the meter and its copies should be in charge of an international committee in which all states interested should be represented." Shortly afterward the French government took the initiative and convoked the International Commission of the Meter which met at Paris on August 8, 1870. Notwithstanding the absence of England and Germany and the interruptions to travel caused by our misfortunes, the delegates, before separating, while postponing the final decision to a more favorable time, discussed the principles on which the new prototype meter should be made. Again called together in 1872, the Commission enlarged its program to include other parts of metrology and especially to an investigation of the kilogram. The French section of the Commission was particularly active in the next few years. H. Deville studied the metals of the platinum group and caused the adoption by the Convention of an alloy of platinum and iridium as the material for the unchangeable prototype standards. Its fine grain, its hardness, its resistance to moisture and oxidation, places it in the first rank of substances adapted to furnish irreproachable standards. The learned chemist was aided by his brother Charles, and by the physicist Stas, Belgian delegate to the conference. After ten years of labor they succeeded in bringing these metals to a state of remarkable purity. "These prototypes," exclaimed J. B. Dumas, "will endure for centuries, even though they may be exposed to dry or to damp

Arago (1786-1853).
Facsimile of a lithograph by Julien.

General Morin (1795-1880).
During the Commune he saved the standard meter from destruction.

air or plunged into the sea. They will come out of the most violent conflagration unharmed and can only be injured by intentional violence, such as the blows of a sledge or the action of lime." In 1874 by means of a special furnace they melted at one time 250 kilograms of platinum iridium. This was no child's play, and then Stas proceeded to make numerous delicate analyses to be assured of the composition of the alloy, while Deville determined its density with rare precision to find if any blow holes or cracks existed in the ingots, the only way the homogeneity of the ingot could be determined. In addition Tresca determined the shape of a bar required to possess the necessary rigidity, and Fizeau, aided by his method of interference, showed how small was the coefficient of expansion. This was important because it reduced the probability of errors in temperature corrections. During this period the governments represented at the Convention were not idle. They gave legislative sanction to the work of the *savants*, without which a unification of measures could not have been accomplished. The celebrated Convention of the Meter was signed at Paris May 20, 1875, and simultaneously ratified by sixteen states, Germany, Austria-Hungary, Belgium, Argentine Republic, Denmark, United

CHARLES and HENRY SAINT-CLAIRE DEVILLE in 1864.

STAS. (1813-1891). Facsimile of an engraving by Danse.

States, France, Italy, Peru, Portugal, Russia, Sweden and Norway, Switzerland, Turkey and Venezuela. They also agreed to support at common expense the International Bureau of Weights and Measures, a scientific organization to be located at Paris. Its operations were to be under the exclusive direction of the International Committee, itself subject to the authority of the General Conference of Weights and Measures composed of delegates from the contracting states. The Committee has met regularly up to the present time, and the Conference has held two sessions, in 1889 and in 1895.

The International Bureau of Weights and Measures, its establishment and its scientific material. The International Commission of 1872 prescribed the principal features of an extensive program to be executed by the physicists of the International Bureau.

The international meter was to be a copy of the meter of the Archives "as it is," and also the kilogram was to be deduced from the kilogram of the Archives. At this point the theoretic men made certain criticisms. They wanted to begin over again with the ideas that inspired the founders of the metric system, and obtain a more exact measure of the ten-millionth part of one-quarter of a meridian by new geodetic measurements and correction of the old prototype.

This was Utopian, for if in twenty-five years with better instruments and extreme care the measurement of the meridian might be made a little more precise, it would still be only an approximation to theoretical accuracy, and it was much wiser to do as the men of 1872 had done, and not commence an endless series of alterations as geodetic methods improved. But many other difficulties were to be overcome to accomplish the work required, to collect the necessary apparatus and install it in a suitable location. The government assisted by vesting a free title in the Committee to the pavilion of Breteuil, the ancient summer residence of the Princess Matilde, in the Commune of Sevres (Seine et Oise), in the middle of a park of venerable trees. Here there are no vibrations such as are caused by the traffic of a great city, and all the conditions are found that are desirable for such an establishment. This appendage to the Chateau of St. Cloud was in ruins, and the first years were spent in re-

The International Bureau of Weights and Measures at Sevres. (Seine et Oise).

building the old and erecting new buildings suitable for the work. We cannot here describe all the arrangements found necessary, but the first instruments were not set up till 1878. They rest on pillars of masonry firmly bedded in the ground. These massive pillars are independent of the floors of the buildings, and so arranged that observations may be made free from errors caused by the proximity of the observer.

We may now inquire what apparatus the International Bureau uses for making measurements, and what work it has already accomplished. First, for measuring length, there are four comparators. These consist

Medal commemorating the Conference of the Meter (1872). Engraved by Chaplain.

essentially of two fixed pillars carrying microscopes provided with micrometers, under which are brought by peculiar mechanism the two scales which are to be compared.

(*To be continued.*)

Notes.

PHYSICS.

The Violet-blue Color of the Electric Arc can be made more yellow by impregnating the upper carbon with calcium or magnesium salts. As it burns more rapidly than the pure carbon rod, it must be made larger in order to last as long.

High Voltage Underground Cable. An underground cable three miles in length at St. Paul, Minn., has recently been successfully tested at 30,200 volts, the highest voltage hitherto obtained with this class of conductors being the 20,000 volts used at Niagara Falls. The cable at St. Paul consists of three copper conductors, each wrapped in paper and the whole encased in lead and laid in vitrified clay conduits. As a result of this test 5,000-horse power at 25,000 volts will be transmitted from Apple River, Wis., to St. Paul, a distance of 27 miles.

The Frequency of an Alternating Current may be measured by the following simple and convenient method: A disk covered with narrow black and white sectors is rotated before an incandescent lamp through which the alternating current whose frequency is to be measured, is passing. The speed of rotation of the disk is varied until it appears to stand still. Then the product of the sectors of one color by the number of revolutions per second gives the number of reversals per second of the current, or twice the frequency. Of course, it may happen that the disk may be revolved at two or more times the proper speed with the effect that it appears to be at rest. In that case, a multiple of the frequency is obtained.

Convenient Mercury Cups may be readily and cheaply made as follows: A cork about two cms. or more in diameter is pierced with a hole about a cm. in diameter only half way through. The cork thus perforated is glued in the middle of a shallow cardboard box, such as those in which Denison's gummed labels come. The cavity in the cork is then half filled with mercury, in which the wires making the electrical connections may be dipped and held in place quite firmly by thrusting them into the cork. The box cover not only gives the cup steadiness, but also acts as a tray to catch the mercury that may be spilled out.

How Welsbach Mantles Are Made.—A six-cord cotton thread is woven on a knitting machine forming a tube of knitted fabric of rather open mesh. This web has the grease and dirt thoroughly washed out of it, is dried, then cut into lengths double that required for a single mantle. It is then saturated with a solution made from monazite sand, which yields in the finished mantle the oxides of thorium and cerium, wrung out, stretched over spools and dried. Next the double length prices are cut into two, the tops of each piece doubled back and sewed with a platinum wire which draws the top in and provides a means of supporting the mantle when finished, from the wire holder. After stretching the mantle over a form, smoothing it down, and fastening the platinum wire to a wire mantle holder, the mantle is burned by touching a Bunsen burner to the top. The cotton burns off slowly, leaving a skeleton mantle of metallic oxides, which are unconsumed, and which preserve the exact shape and detail of every cotton fiber. The soft oxides are hardened by a Bunsen flame. During burning out and hardening, considerable shrinkage takes place. The mantle is finally immersed in crystalline to prepare it for transportation, and packed.

GEOLOGY.

The Flow of Rocks.—Prof. Frank D. Adams, of McGill University, has recently shown that rocks may be made to flow by subjecting them to enormous pressures. Marble was used in most of the experiments. Cylinders of it were fitted into wrought iron tubes of great strength, in

either end of which played heavy steel cylinders. The marble was then subjected to pressures of nearly a hundred tons per square inch, often for several months at a time. The iron tubes were found to bulge out, and when they were cut away blocks of solid marble were obtained, which had changed in shape considerably and which were only about half as strong as originally. If, however, the pressures were applied while the marble was heated up to temperatures of 300 degrees C. to 400 degrees C., it flowed much more readily and the resulting block was but little weaker than the marble taken.

Ocean Depths.—The "Outlook" publishes under the authority of Professor J. E. Jenks, one of the editors of the "Army and Navy Register," the discovery of a greater depth in the ocean that has hitherto been recorded. The vessel Nero, engaged for the last few years in surveying a cable route across the Pacific, has reached a depth of 5,269 fathoms and 5,160 fathoms at a point between the Midway Islands and the Island of Guam, a little east of the latter. Previous soundings in the same region had shown a depth of 4,900 fathoms. At 5,070 fathoms there was a temperature of 39.5 degrees F. and at 5,101 fathoms 36 degrees F.

A submarine range of mountains was also located between Guam and Yokohama, connecting the range that was known to exist between Japan and the Bonin Islands with the Island of Guam. A large peak on this range, comparable to the peak of Fusiyama, reaches within 480 fathoms of the surface.

Two Pamphlets of very considerable interest to instructors in geology and physiography appeared last summer. These are: *Profiles of Rivers in the United States,* by Henry Gannett, being No. 45 of "The Water Supply and Irrigation Papers" issued by the Geological Survey, and *A Guide to Geology and Paleontology of Niagara Falls and Vicinity,* by A. W. Grabau, Bulletin 45 of the New York State Museum.

The first of these contains eleven plates illustrating the slope of 100 rivers of the United States, with about 100 pages of descriptive text. In the text we find information as to the source of the river, its extent and the character of its drainage basins, details of slope, etc. In a table accompanying the description are given details as to the distance from the mouth, the elevation above the sea and the rate of fall per mile at important towns in the course of the stream. The plates are drawn with a horizontal scale of 100 miles to the inch and a vertical one of 2,000 feet to the inch. This gives the streams of the coast ranges a seemingly exaggerated steepness of slope, while the Mississippi river shows no apparent fall for many miles from its mouth; but the advantages in the use of a single scale for all rivers is evident. The pamphlet will be of great use to the teacher of physiography in illustrating comparative lengths and slopes of streams; also the relative steepness of slope at head and mouth of rivers. The effects of rejuvenescence, of local geological barriers and

other points in the history of the stream are splendidly shown if the plates are considered in connection with appropriate maps. The pamphlet may be obtained free by applying to the Director of the United States Geological Survey.

The second pamphlet has been prepared as a guide to Niagara Falls for the visitors to the Pan-American Exposition at Buffalo; its 286 pages are divided into five chapters, with an introduction and appendix. The first three chapters treat of the physical geography of the Niagara region, the life history of the Falls and the stratigraphy of the region; this portion is illustrated by fourteen good plates, showing scenes of the falls, gorge, etc.; and thirty-four text figures showing details of structure. Accompanying the Bulletin is a large-size map, covering geologically the region from Buffalo to Lake Ontario. The last two chapters describe the fossils of the Niagara region and the Post-Pleistocene fossils of the Niagara River gravels; 190 figures of fossils are given. The appendix contains a valuable bibliography of the falls and a glossary of geological terms. The pamphlet may be obtained from the Director of the State Museum, St. Albany, N. Y.; its price is 65 cents.

Book Reviews.

Elements of Astronomy. By Simon Newcomb, Ph. D.; LL. D., formerly Professor of Mathematics and Astronomy in Johns Hopkins University. 13x19 cms., 140 pages. American Book Company, Chicago. $1.00.

This pleasing little volume attempts merely an untechnical presentation of those facts and laws of astronomy which are of most interest and importance to the general public and, in the execution of this attempt, to avoid as far as possible the necessity for formal mathematics. For the general reader both these objects are certainly praiseworthy; but for instructional purposes in the public schools there is place for legitimate difference of opinion as to whether the prevailing and growing custom of eliminating from text-books in the semi-mathematical subjects of physics, astronomy, etc., designed for the elementary and secondary schools, substantially everything involving mathematics is not in great danger of enervating the scientific work of these curricula by the presentation of fragmentary and distorted, if not spineless, views of the sciences. This tendency has already been carried so far that schoolmasters show a disposition to regard only the qualitative aspects of science as of any value,

or importance, in instruction and to look upon the introduction of its quantitative aspects as the lugging in of an artificial something to serve merely, or mainly, as the foundation for the teaching of mathematics. This tendency is, of course, regrettable in the extreme.

The reputation of the great author of this book is sufficient guarantee of its excellence both as a popular and accurate scientific presentation of the substance of the science. Rare sagacity and deep discernment are manifest throughout, both in the choice of representative topics and in the order and manner of their elucidation. This little book is another of the many proofs the scientific reader has had of late that Professor Newcomb possesses to an eminent degree the rare faculty of being able to condense the results of science without squeezing the juice out of them, of being interesting and at the same time scientific.

The publishers have maintained their high reputation as text-book makers both in the cuts and in the typography. Among those who sympathize with the reduction of mathematical demands in elementary science teaching to a minimum this book will doubtless secure the wide adoption it deserves.

G. W. M.

An Elementary Treatise on Qualitative Chemical Analysis. By J. P. SELLERS, A. M., Professor of Chemistry, Mercer University, Macon, Ga. 19x13 cm., 157 pages. Ginn & Co., Boston, 1900. 80 cents.

The author of this book aims to avoid unnecessary details as well as extreme condensation. It is a modern book. In addition to a judicious selection of qualitative methods, the book contains seventy-five pages devoted to the theory, methods and systems of qualitative analysis, the application of the theory of ions to qualitative reactions, and a brief treatment of spectroscopy. These topics are clearly treated and adequately illustrated by experiments and diagrams. If any criticism were to be made of these features, it is that the treatment is too condensed for a beginner and too brief for an advanced worker. On the other hand, the author is to be commended for incorporating such needful matter into a book which is the bridge from general chemistry to quantitative analysis. Another new feature is the application of Reddrop's system of normal solutions to qualitative work. The methods of separation are often duplicated, and the student is encouraged to exercise his judgment in selecting the best method. Mechanically the book is most praiseworthy. This fact will contribute materially to the design of the author, viz., to provide "a course short enough to be digested during the time allotted in an ordinary college curriculum."

L. C. N.

Introduction to the Study of Zoology. By N. A. HARVEY, Head Department Science, Chicago Normal School. 13x19 cms., 208 pages. Western Publishing House, Chicago. 88 cents.

This book is written from a pedagogical standpoint and shows clearly

the value of zoölogy as a teaching subject. The author has shown that zoölogy is the most logical of high-school subjects, and if the greatest benefit is to be derived from it, it is one that throws a great strain on the student. Zoölogy taught from a developmental standpoint will also change the teacher's attitude and make him present the subject in a clearer way.

The first part of the work is on the insects. Different types of these are used to represent different families. The resemblances of these Families are brought out by the student and the idea of an Order developed. Then types of Orders are studied, and from these the conception of Class is drawn. Next the idea of Branch is developed and, as a final step, the student is brought to the knowledge of the essentials of an animal. But in order to do this the student has had to keep in mind, in usable shape, all the work of the year.

The laboratory outlines, which make up the greater part of the book, are very good, the best that the writer knows. They are not too full to tire a high-school student and are full enough to develop the subject clearly. They give what is needed—a clear, first-hand knowledge of the type specimens studied.

Several other features of the book are very good. Under the head of additional facts the author has added enough material not obtainable by the student during the laboratory period to take the book out of the list of pure laboratory guides. With the aid of these statements and by judicious questioning he has developed a considerable amount of animal ecology, without giving it that specific name. His development of Von Baer's principle is excellent, and will be quickly grasped by the average high-school student. The general hints on collecting are very useful. The analytical keys appended are an excellent feature and show that such work can be done in the high school.

The writer believes that the book would have been helped by the addition of a little bibliography.

The book is an excellent one for high schools and academies and deserves a wide use.

Kansas City Central High School..........................PORTER GRAVES.

The Elementary Principles of Chemistry. By A. V. E. YOUNG, Professor of Chemistry in Northwestern University. 13x10 cms. XIV. and 252+106 pages. D. Appleton & Co., New York, 1901. $1.10.

The method of beginning the study of chemistry by having the student get his knowledge first-hand in the laboratory is becoming more and more popular every year, especially as the obstacles to laboratory equipment are being surmounted. The book at hand carries out this method in its entirety; the student performs "the experiment illustrative of a topic before he gives attention to the fuller presentation of the same in the text." The book is accordingly divided into two parts, the first part con-

taining the text and the second, the experimental illustrations. By a system of marginal numbers the two parts are brought into close connection.

Many of the experiments are quantitative, but do not on that account demand an extensive laboratory equipment for their successful performance. Quantitative work is indeed necessary to illustrate the fundamental laws and principles of chemistry, and anyone teaching *chemistry*, and not wholly *chemicals*, will allow this claim. As the title of this book implies, it is mainly devoted to the underlying principles of the science, and yet there is enough matter of a descriptive kind to cover what is usually given in elementary courses.

Books based on laboratory methods and quantitative work may indeed be considered by some teachers to be too difficult. This difficulty is not, however, one that the pupil has, but one that the teacher has. A poorly prepared teacher cannot teach well according to the laboratory methods, where he is, so to say, right in the presence of nature, however fine a showing he can make by text-book methods. The adoption and use of a book of this nature is in a way a testimonial to the ability of the teacher. While this book is perhaps above the average teacher, it is not above the average student. To help the teacher to teach his book, Professor Young has in a "Guide" gone over the subject matter in detail and in a most thorough and personal way. These "Suggestions to Teachers" form a most valuable course for the chemistry teacher, either embryonic or mature. He will find in it much that is clear and suggestive, and that will give him considerable help in his teaching. As a book for teachers this chemistry takes high rank.

One of the most admirable features of the book is the breadth of view manifested; chemistry is not regarded as isolated, but as wrought into an integral whole with other branches of knowledge. Humanistic touches here and there also vivify the subject matter, and the excellent reproductions of the portraits of the founders of the science contribute to interest and hold the student. Its "culture value" is also great. The strictness of logic employed in passing from facts to laws and from laws to theories, the nicety of choice in the experimental illustrations and the fair, almost "legal" definiteness and clearness of statement stamp this book with a worth peculiarly its own.

C. E. L.

The Metric System. By S. Jackson, M. A., with an Introduction by J. Emerson Dowson, M. Inst. C. E. Allman & Son, Limited, 67 New Oxford Street, W. C., London. 1900. 99 pages.

The design of this book is to aid in the introduction of the metric system in England. There are two ways, the author remarks, in which this important reform can be helped along—first, by teaching the principles and facts of the system in the public schools; second, by showing its advantages to those engaged in commerce and trade. The book aims to cover both

these points. Part I treats of metric principles, arithmetical notation, calculation of prices, etc.; Part II, of practical details—length, area, volume and weight, applied to various trades; Part III, of decimal coinage—a reform very much needed in Great Britain. The superiority of decimal weights and measures can in no way be better[2] appreciated than by contrasting the awkwardness of computing values by English pounds, shillings and pence, with the perfect simplicity of our own decimal money. Let any American carefully study Part III of this book, and if he doesn't become a convert to metric weights and measures his case is hopeless.

The principles of the system are clearly defined. From the simplest facts of notation to the most complex calculations the progress is by easy steps. The work is without illustration—except half a dozen geometrical figures—a noticeable defect. There are no answers to the exercises. The customary metric abbreviations are mostly omitted. *Centare* is written *centiare; kilo* is *kilog.* The French spelling of *metre* is employed and the English of *gram.*

In surveyors' measure a strong point might have been made of the decimalization of the chain—about the only decimal thing of which the English people can now boast, except in science. Computation of weight from volume, by use of specific gravity, would also have been a valuable addition.

There is an excellent table of modern coinages, which shows all nations except the United Kingdom, Australia and India, users of decimal coinage. A similar table of weights and measures exhibits the almost universal adoption of the metric system. Japan is classed as a *metric* country; *decimal* would be more accurate.

The exercises cover all sorts of arithmetical problems. To us it seems odd to read of the *stone,* the *kilderkin,* and of *oldish* hay in distinction from new hay and old hay. As a whole the book is an excellent *arithmetic of the metric system,* with just enough history and statistical matter to make it interesting.

R. P. W.

The Plant Societies of Chicago and Vicinity. By DR. HENRY C. COWLES. 18x26 cms., 76 pages. The Geographic Society of Chicago. 1901.

This pamphlet forms the second bulletin of the Geographic Society of Chicago. It is divided into three parts, of which the first contains a short discussion of the principles of classification of plant societies; the second a consideration of such societies as are found in this region, and the third a list of the localities about Chicago which are of interest botanically, together with the plant societies which may be studied in each.

The author points out for the first time the intimate relation which exists between the plants of a given area and its topography; further that, as a topographic form is altered by erosion and weathering, a corre-

[2]Review of S. J.'s Met. Sys.

sponding change takes place in the vegetation; and that just as a base level is the final result of erosion, so a mesophytic plant society is the climax stage in the floral history of a region. Whether the plant cycle exactly corresponds with the erosion cycle depends upon a number of factors, of which climate, latitude and soil are the most important. Here then is a basis for the classification of plant societies which is at once natural and adequate, and which takes into account the gradations between the various societies.

Of general interest is the discussion of the plant societies of the Chicago region. These have been divided into two groups: the Inland and the Coastal. Under the first head three series are considered: (1) the River Series, with its development from the ravine to the flood plain stages; (2) the Pond-Swamp-Prairie Series, and (3) the Upland Series. Of the Coastal Group the Lake Bluff Series and the Beach-Dune-Sandhill Series are discussed.

Although the plants named in this paper are those found about Chicago, nevertheless the consideration of the factors which control the distribution is taken up on such broad lines that it will be invaluable to botanists outside of Chicago, and of much interest to general readers everywhere.

To teachers of elementary botany it suggests a line of work which will supplement the laboratory instruction, and instead of the dry bones of plant analysis will afford the pupil a living subject for observation and study. It is an exposition of a relatively new line of botanical work—a line which is destined to become a leading one in elementary and secondary schools.

W. W. ATWOOD.

Books Received.

A Laboratory Course in Plant Physiology, especially as a Basis for Ecology. By William F. Ganong. Henry Holt & Co., New York, 1901. vi and 147 pages.

Introduction to the Study of Zoology. By N. A. Harvey. Western Publishing House, Chicago, 1901. 208 pages. 88 cents.

Lincoln in Story. Edited by Silas G. Pratt. D. Appleton & Co., 1901. 224 pages. $1.00.

Science Primers. History of Philosophy. By Thomas Hunter. American Book Co., 1900. 128 pages. 35 cents.

A Brief Course in General Physics. By George A. Hoadley. American Book Co., 1900. 463 pages. $1.20.

Elements of Astronomy. By Simon Newcomb. American Book Co., 1900. 140 pages. $1.00.

CLEARING HOUSE.

Teachers desiring to offer for exchange books, apparatus, etc., may insert a notice to that effect at the nominal rate of one cent per word, *in advance*.

Reports of Meetings.

N. E. A. ROUND TABLE CONFERENCE ON ZOÖLOGY.

THURSDAY, JULY 11, 3:00 P. M.

Dr. Franklin W. Barrows, Central High School, Buffalo, N. Y., *Leader.*
Grace F. Ellis, Grand Rapids, Mich., *Secretary.*

The leader, in proposing topics for discussion, presented the following: *Theses on Zoology in Secondary Schools.*

1. Laboratory and field study should form the basis of the entire course and should be allotted at least half the time of the course.

2. The most profitable study of any organism takes into account not only its actions during life, but also its structure, both internal and external, as revealed by dissection.

3. Every student of zoölogy should practice the use and application of the compound microscope.

4. No plan has yet been devised by which zoölogy classes in cities can do even a fair amount of field work.

5. Since the pupil cannot go to the animals, the animals must be brought to him; aquariums and vivariums should be the centers of interest in every laboratory.

6. A liberal use of photographs, lantern-slides, charts, and illustrated books will economize both time and effort. Museum specimens and anatomical preparations are useful for the same reason.

7. The subject of economic zoölogy is of transcendent value and should be prominent in every course of study. The career of the English sparrow and gipsy moth in this country and of the mongoose in Jamaica, the importation of insects to the Pacific coast to fight the orange scale, and of others to fertilize the fig-trees, these are not only interesting zoölogic episodes but important economic revolutions. The life histories of mosquitoes, flies, tape-worms, the trichina, and the close association of these and other pests and parasites with diseases of man and domestic animals should be matters of common information in all our schools. So,

also, the valuable services of many despised animals, such as toads, snakes, and birds, should be thoroughly taught.

Mr. Murbach, of Detroit, was called upon to open the discussion, and in response said that to him the most important subject was that referred to as No. 2 of the theses. He referred to the much-discussed subject of dissection. He thought that dissection properly taught did not encourage cruelty in children, and considered a moderate amount of it indispensable. The objections of pupils to handling animals are decreased by beginning with the lower forms. Time may be saved in the study of some forms by the use of dissected preparations in the laboratory. At present there seems to be a reaction in favor of less dissection.

Mr. W. H. MacCracken, Buffalo, N. Y., believed that it was a mistake to expect the beginner in zoölogy to pay much attention to minuteness of detail in dissection. In place of the fine points of anatomy often insisted upon, he favored a few simple demonstrations of function by vivisection.

Principal Wm. J. S. Bryan, Normal and High School, St. Louis, Mo., attributed to lack of experience the repugnance of pupils to handling most forms of animals. When interest has been aroused this aversion is removed. Mr. Bryan asked, "How much use of the compound microscope is profitable? Will a simple lens answer all purposes?"

The leader, in reply, said that the pupil should first be trained to use his own eyes "for all they are worth." After this he should acquire the power to use the compound microscope because the instrument may be of great service to him in the future. The technic of the instrument is simple, and no school should deprive its pupils of the practice necessary to make them independent in its use.

Mr. Murbach, in response to a question, gave a brief outline of the course in Detroit and said the present tendency is to emphasize somewhat the living animal by such harmless experiments as tying the fins of a fish in order to learn their function, or studying the earthworm in glass tubes or cases filled with soil.

Mr. MacCracken approved the course just outlined rather than one which devotes the whole time to the study of one or two types. He quoted a student who had passed through such an experience and complained that "for him, zoölogy had too much *froginess.*"

Another teacher said her experience proved that repugnance to handling animals could be largely overcome, and that in her estimation experiments with living animals were extremely valuable.

Some other theses were then briefly touched upon, Nos. 5 and 6 being emphasized in order to overcome the difficulty mentioned in No. 4.

Mr. MacCracken distributed some photographs of birds and fowl taken by himself, and at the request of the leader, read a paper on "The Camera in Zoölogy." In his opinion, camera views presented many advantages over drawings as far as accuracy is concerned. Mr. MacCracken also

thought that drawing did not always tend to more accurate observation of an object, and that scientific photography, while by no means fully developed, afforded great possibilities for scientific information and research.

N. E. A. ROUND TABLE CONFERENCE IN PHYSIOLOGY.

THURSDAY, JULY 11, 4:30 P. M.

In the absence of Mr. Jas. E. Peabody, teacher of physiology in Peter Cooper High School, New York City, and leader of this conference, Pres. W. J. S. Bryan took charge. He spoke of the bearing of physiology on every-day life, the time to be given it in school, and said:

"Physiology has long been accorded a place in the high-school curriculum; its importance has been recognized. But those who have taught it have not yet devised means for its teaching by the methods now regarded as essentially scientific. That the same can be done for physiology as has been done for botany and physics and chemistry is not to be questioned."

After this, Mr. L. Murbach, of Detroit, was called upon and spoke along the line of laboratory work and the laboratory methods in physiology. "While it is difficult to treat human physiology in the high-school by the laboratory and experimental method, the combination of physiology, hygiene, and sanitation can be thus treated. This is, in any case, a good combination for the high-school subject to be known as physiology. Much stress should be laid on teaching at least half the subject by the laboratory method. This is best done in connection with the text, or rather to precede its use. The function of blood, for example, should be preceded by the observation of blood-vessels in a live earth-worm and then in a frog's foot. Physiology, when thus taught, should be recognized by higher institutions as equivalent to the same amount of other biological training."

Mr. S. B. MacCracken, of Buffalo, emphasized what had been said about laboratory work in physiology, and showed the help gained from getting pupils to study their own bodies, muscles, etc. That actual specimens should be studied, for human anatomy, even as given in Gray, is not exactly like specimens.

Miss Grace Ellis, of Grand Rapids, spoke of simple, home-made apparatus, and described a spirometer. Her pupils learned some interesting things from it, as lung capacity. The knowledge was applied in proper exercise, and the capacity of the lungs increased, as shown by measurement.

By request, Mrs. Laverne Bassett spoke on the impracticability of teaching physiology to pupils of the ninth grade, on account of their immaturity and the consequent trouble they had in understanding the subject or the text. That she had done it, to some extent, at least, by the laboratory methods, even on benches. Miss Pettee, of the Eastern High School, spoke also in favor of the laboratory method.

Mr. S. O. Mast, of Hope College, Holland, Mich., reported a year's experience in introducing laboratory work in physiology. He used Peabody's Laboratory Exercises, and found it an admirable book for the purpose. The course was entirely successful, and can be repeated for 25c per pupil if they pay for the material used. He emphasized the fact that the text-book may not be neglected, but should be used fully half the time. In answer to a question from the chairman, he said he used the book after observation and experimental work.

Dr. Barrows was asked to give his opinion on the relation in time and value between zoölogy and physiology. He said that much physiology can be taught in a course in zoölogy, but from the standpoint of zoölogy, the course in physiology should come first.

Reported by L. MURBACH.

Correspondence.

Editor SCHOOL SCIENCE.

DEAR SIR: In the April number I discussed the demand for science teachers. It may be of interest to compare the tabulation for this year with that of last. It will be seen that science still holds its place at the head. In nearly every case but one or, at most, two lines of work were specified. In the classification given below each request appears under such subject included in it.

Science, general, 16; physics and chemistry, 5; biology, 4; chemistry, 1; science with English, 2; with mathematics, 1; with Latin, 1; with history, 1. Total, 31.

English only, 9; English with Latin, 9; with history, 3; with German, 2; with science, 2; with art, 1. Total 26.

Latin only, 4; Latin with English, 9; with German, 5; with mathematics, 4; with science, 1; with Greek, 1. Totai, 24.

German only, 2; German with Latin, 5; with French, 3; with English, 2; with commercial work, 1. Total, 13.

Mathematics only, 3; mathematics with Latin, 4; with science, 1. Total, 8.

French with German, 3; with commercial work, 1. Total, 4.

History only, 1; history with art, 1; with English, 1. Total, 3.

Art only, 1; art with history and English, 1. Total, 2.

Drawing and surveying, 1; commercial work, 3.

Athletics with other subjects (mostly science), 6.

Music (the ability to sing and to lead the opening exercises, at least,) was required in five cases and mentioned in others.

Stratton D. Brooks.
High School Visitor and Assistant Professor of Education, University of Illinois.

Editor School Science.

Dear Sir: A statement of fact in President Harvey's address, as reported in the last number of School Science, strikes me as so remarkable that I feel impelled to ask for more light. That the "relative accuracy" of two classes in the physical laboratory should bear to each other the ratio of "seven to three," is, to me, an absurd statement, to which I can attach no definite meaning. Perhaps a fuller knowledge of the circumstances and data would make it plain and reasonable, but it is far from so at present.

Nor do I see the connection between the want of "accuracy" in his high-school graduates and the assumed cause in the lack of professional training of their instructors. It strikes me that a "physicist" would certainly teach "accuracy," whatever else he might fail to do. But possibly I misunderstood President Harvey's meaning. I certainly agree with him fully concerning the desirability of a better insight into the philosophy of education by science instructors.

Sincerely,

Chicago, Sept. 26, 1901.

A. W. Augur.
Lake View High School.

[In reply to the above letter permit me to say that I fully expected some one to express astonishment at the statement concerning the accuracy of the two classes referred to, and am quite prepared to state the facts in the case. The classes were found in the Wisconsin State Normal School at Superior. Each year for three successive years the high-school graduates were taught in physics in one class and those who were not high-school graduates constituted another class. All of the

high-school graduates had studied physics previously, otherwise they were not considered as high-school graduates for purposes of this division. There were approximately equal numbers in both classes each year, about thirty in each class.

The two classes did identical work on the same day. They used the same room, same apparatus, same teacher, same laboratory guides. The work was a series of exercises drawn from the Hall and Bergen Physics. The exercises included the determination of the law of elasticity in wires; laws of bending in rods, three exercises; laws of torsion, three exercises; the coefficient of linear expansion by heat, two exercises; the latent heat of melting; latent heat of boiling; specific heat of a solid; the laws of a pendulum, and the laws of falling bodies.

In making these determinations, the students did individual work. Each student worked alone unless the exercise was of such a nature that the co-operation of two or three was necessary to perform the exercise. They tabulated the results, and each one sought to determine for himself the law. In the final class discussion of the exercise, the tabulated results of all the pupils in each class were averaged and the average result in each class was made the basis of the discussion of the problem. It is the average result of the work of each class expressed in figures for every exercise that I referred to in my statement concerning the accuracy of the two classes. In seven cases out of every ten the average result of all the pupils in the class of high-school graduates differed more widely from the correct amount than did the average result of all the pupils in the class who were not high-school graduates. For example, in the determination of the distance that a freely falling body will travel in the first second of its descent, my last class of high-school graduates obtained a result differing from the distance stated in the text books by about 10 per cent; the class who had never studied physics missed it only by 3 per cent. The preceding year, the class of high-school graduates erred in the same exercise about 11 per cent. The other class about 6 per cent. That is, the average result of all the pupils in each class differed from the accepted amount by the per cent stated.

The difference in accuracy was so pronounced and so unexpected that it attracted my attention in my first year's classes very soon. Thereafter I kept a record of the results of each class, and 7 to 3, or seven out of ten, is a conservative estimate.

It was a case peculiarly favorable for comparison. The exercises upon the bending of rods, twisting of rods, and the stretching of wires were as unfamiliar to the one class as to the other. The class of high-school graduates were of course more or less familiar with what the result should be in the exercises concerning the laws of the pendulum, the laws of falling bodies, and the laws of heat. This seemed to have no effect upon the relative accuracy of the laboratory determinations.

Concerning the previous study of physics by the high-school graduates

I have no definite knowledge. From casual conversations and inquiries I judge the following statement of that condition to be fairly just. All of them (the graduates) had used a text book, and I believe in almost every case it was Avery's Physics, an excellent book of its kind. All or nearly all had done some laboratory work, although the greater part of it had consisted of demonstration exercises intended to illustrate the text. Such exercises had been carried on, no doubt, with a full knowledge of what the result should be. In many cases the laboratory had been poorly equipped, and in some no attempt had been made to do laboratory work. Perhaps twenty high schools were represented in each class.

With regard to the average ability and intellectual culture of the two classes, if there was any difference, it was in favor of the graduates. In the relations to the teacher, there was the warmest sympathy existing in every instance between teacher and pupils in every class.

These are the facts in the case. They may be absurd, as your correspondent states, but for that I am not responsible. I was informed by my successor, Mr. Merrill, at the conclusion of the reading of the paper at Detroit, that the same conditions had prevailed in the classes of the succeeding year. He had also kept a record of the results. There can be no question about the facts. The explanation of them is the thing in which diversity of opinion will no doubt exist.

My own opinion is that the use of the text book in connection with laboratory work is detrimental to the development of that kind of power that is needed to obtain accurate results in such laboratory work as I set my classes to do. My conclusion is that if *power to do* is sought for, text books and reference books should be rigidly excluded from the laboratory. If knowledge of the greatest number of facts in the least possible time is the end sought, the text book should be used. There can be no compromise between the two. It has been my own opinion that power to do things is the more valuable acquisition and the more difficult to obtain, and for this purpose, no book should be allowed to stand between the pupil and the object studied.

Chicago, Sept. 28, 1901. N. A. Harvey.

QUESTIONS FOR DISCUSSION.

Teachers are invited to send in questions for discussion, as well as answers to the questions of others. Those of sufficient merit and interest will be published.